Great Lakes Fruit, Vegetable & Farm Market EXPO
Michigan Greenhouse Growers Expo
December 8-10, 2009
DeVos Place Convention Center, Grand Rapids, MI

Michigan Water Use Legislation and Irrigation Management

Thursday morning 9:00 am
Where: Grand Gallery (lower level) Room A-B
CCA Credits: SW(3.0)

9:00 a.m. Working Through the New Legislative Process for New Large Volume Withdrawals in Michigan
- Steve Miller, Biosystems Engineering Dept., MSU

9:50 a.m. Irrigation Scheduling and New Scheduling Tools
- William Northcott, Irrigation Specialist, Biosystems & Agricultural Engineering Dept., MSU

10:50 a.m. Irrigation System Evaluations and Economics
- Lyndon Kelley, Extension Educator Irrigation, MSU-Purdue

11:30 a.m. Comparing Energy Sources for Irrigation
- Lyndon Kelley, Extension Educator Irrigation, MSU-Purdue
Michigan Water Withdrawal Legislation

Steve Miller
Bill Northcott
Department of Biosystems and Agricultural Engineering
Michigan State University

http://www.miwwat.org/

Zone A Zone B Zone C Zone D

• Zones are set by law
• Numerical values are different for each stream type

Interpreting the Fish Curves

Adverse Resource Impact

Interpreting the Fish Curves

Adverse Resource Impact

Requirements that Large Capacity Withdrawals (LCW) not cause an Adverse Resource Impact (ARI)

<table>
<thead>
<tr>
<th>Date</th>
<th>Quantitative</th>
<th>Narrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/9/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/1/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/28/2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/9/2008</td>
<td></td>
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</tr>
</tbody>
</table>

Narrative: Shall not functionally impair a stream's ability to support characteristic fish populations.
Quantitative: Withdrawal limited to percent reduction of Index Flow as specified in legislation (max 25%).

Water users committees
- All persons making LQWs within a watershed are encouraged to establish a water users committee to evaluate the status of current water resources, water use, and trends in water use within the watershed and to assist in long-term water resources planning.
- A water users committee may be composed of all registrants, permit holders, and local government officials within the watershed.

Water resources assessment and education committees
- The notified entities may form a water resources assessment and education committee in order to:
  - assess trends in water use in the vicinity of the withdrawal
  - educate water users
- The MDEQ shall assist in the formation of water resources assessment and education committees and may provide them with technical information regarding water use and capacity within their vicinity, aggregated at the stream reach level.
Water resources assessment and education committees

- Committee meetings shall be open to the general public.
- Water resources assessment and education committees may provide educational materials and recommendations regarding any of the following:
  - Long-term water resources planning
  - Use of conservation measures
  - Drought management activities
  - Other topics related to water use as identified by the committee

Regulatory “teeth” – Civil Actions

- Effective Oct. 7, 2008, the MDEQ may request the AG to commence a civil action for a violation under this part, including falsifying a record submitted under this part.
- The court of jurisdiction may restrain the violation and require compliance. It may also impose a civil fine:
  - For a person who knowingly causes an ARI with a LOW, a civil fine of not more than $10,000.00 per day of violation.
  - For all other violations of this part, a civil fine of not more than $1,000.00.
  - In addition, the AG may file suit to recover the full value of the costs of surveillance and enforcement by the state resulting from the violation.
Irrigation Scheduling

Overview and Tools

William Northcott
Department of Biosystems and Agricultural Engineering
Michigan State University
Great Lakes Fruit, Vegetable and Farm Market EXPO
December 10th, 2009

Process of maintaining an optimum water balance in the soil profile for crop growth and production

Irrigation decisions are based on an accounting method on the water content in the soil

Irrigation Scheduling

Reasons for Irrigation in Fruits and Vegetables

- Crop Growth and Development
  - Meeting the daily water use requirements
- Crop Establishment
  - Transplants need water in excess of normal crop water use
- Frost Protection
  - Sometimes requires more than one type – overhead for frost protection along with drip irrigation.
- Chemigation / Fertigation
- Herbicide Activation

Components

- Plant Growth Stage and Water Use
- Soil Water Holding Capacity
- Evaporative Demand
- Rainfall / Irrigation
- RECORDKEEPING

Components

- Levels of Accounting
  - 0 – Guessing (irrigate whenever)
  - 1 – Using the "feel and see" method
  - 2 – Using systematic irrigation (ex: ½” every 4th day)
  - 3 – Using a soil moisture measuring tool to start irrigation
  - 4 – Using a soil moisture measuring tool to schedule irrigation and apply amounts based on a budgeting procedure
  - 5 – Adjusting irrigation to plant water use, using a dynamic water balance based on budgeting procedure and plant stage and growth, together with a soil water moisture measuring tool.

RECORDKEEPING

Irrigation Scheduling

- Components
  - Plant Growth Stage and Water Use
  - Soil Water Holding Capacity
  - Evaporative Demand
  - Rainfall / Irrigation
  - RECORDKEEPING
Plant Growth and Water Use

- Fundamentally crops use water to facilitate cell growth, maintain turgor pressure, and for cooling.
- Crop water use is driven by the evaporative demand of the atmosphere.
- Function of temperature, solar radiation, wind, relative humidity.
- Example, a fully developed corn crop in Michigan can use as high as 0.35 inches per day (~9,500 gallons / acre)
- Generally, optimum crop growth and health occurs when the soil moisture content is held between 50 – 80% of the "plant available water"

Estimating Plant Water Use

- Crop water use = Evapotranspiration (ET).
- A "potential reference ET (PET)" can be calculated based on weather conditions.
- The standard method – Penman – Monteith.
  - Based on temperature, solar, humidity, wind, rainfall
  - "Well watered grass"
- Michigan Agricultural Weather Network (MAWN) calculates hourly PET at each station and publishes the daily total value for irrigation use.
  - http://www.enviro-weather.msu.edu/

Estimating ET for Different Crops

- Combining a "Crop Coefficient Curve" with the reference ET.
- Crop Curve is a relationship between the specific plants' growth characteristics and its water use relationship to the reference crop.

Crop Curve

![Crop Curve Diagram]

<table>
<thead>
<tr>
<th>Crop</th>
<th>Kc Coefficient</th>
<th>Reduction in ET (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squash</td>
<td>6-15</td>
<td>46-70</td>
</tr>
<tr>
<td>Cucumber</td>
<td>15-20</td>
<td>46-80</td>
</tr>
<tr>
<td>Cantaloupe</td>
<td>6-10</td>
<td>35</td>
</tr>
<tr>
<td>Watermelon</td>
<td>20-30</td>
<td>not reported</td>
</tr>
<tr>
<td>Tomato</td>
<td>35</td>
<td>not reported</td>
</tr>
<tr>
<td>Average</td>
<td>13.30</td>
<td>13.30</td>
</tr>
</tbody>
</table>

**TABLE 1:** Approximate reductions in Kc and surface evaporation and increases in transpiration for various horticultural crops under complete plants matched as compared with no match using trickle irrigation.
Irrigation Scheduling

- Components
  - Plant Growth Stage and Water Use
  - Soil Water Holding Capacity
  - Evaporative Demand
  - Rainfall / Irrigation

RECORDKEEPING

Soil Water Holding Capacity

- Soil act as a reservoir to hold water for plant use.
- The capacity for a soil to hold water is primarily based on the soils texture but can be modified by attributes such as soil organic matter.

Soil Water Holding Capacity

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Range (in/in)</th>
<th>Average (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very coarse- to coarse-loamy sands and fine sands</td>
<td>0.04 - 0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>Coarse- to fine silty loams and very fine sands</td>
<td>0.08 - 0.10</td>
<td>0.08</td>
</tr>
<tr>
<td>Moderately coarse-textured sandy loams and fine sandy loams</td>
<td>0.10 - 0.15</td>
<td>0.13</td>
</tr>
<tr>
<td>Moderately fine- to coarse sandy loams, loams and silty clays</td>
<td>0.15 - 0.18</td>
<td>0.16</td>
</tr>
<tr>
<td>Moderately fine-textured sandy loams, clay loams, clay, and silty clay loams</td>
<td>0.18 - 0.21</td>
<td>0.18</td>
</tr>
<tr>
<td>Fine-textured sandy clays, silty clays, and clay</td>
<td>0.16 - 0.21</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Available water for each soil group by soil horizon from NRCS Soil Surveys

Example – Oshtemo Soil

Available water holding capacity of soil (inches water per inch soil) from NRCS Soil Surveys.
Soil Example

- Tomatoes on a Oshtemo soil
- Available water is 0.13 in/in
- 2 foot effective rooting zone
- Total available water storage in the soil profile at full crop development
  - 24 inches * 0.13 in/in = 3.12 inches

Oshtemo Soil Example

<table>
<thead>
<tr>
<th>Depth (inches)</th>
<th>Storage per Layer</th>
<th>Cumulative Storage (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 6</td>
<td>6&quot; * 0.125&quot; water storage / &quot; soil</td>
<td>0.75</td>
</tr>
<tr>
<td>0 - 12</td>
<td>6&quot; * 0.125&quot; water storage / &quot; soil</td>
<td>1.5</td>
</tr>
<tr>
<td>0 - 18</td>
<td>6&quot; * 0.125&quot; water storage / &quot; soil</td>
<td>2.25</td>
</tr>
<tr>
<td>0 - 24</td>
<td>6&quot; * 0.150&quot; water storage / &quot; soil</td>
<td>3.15</td>
</tr>
</tbody>
</table>

Measuring Soil Moisture

- Tensiometers and Watermarks
  - Measure soil tension - centibars
- Volumetric Probes
  - TDR
  - FDR
- Capacitance Probes
- Moisture by Feel

Tensiometers and Watermarks

http://www.specmeters.com/Soil_Moisture/

Volumetric Moisture

Irrigation Scheduling

- Components
  - Plant Growth Stage and Water Use
  - Soil Water Holding Capacity
  - Evaporative Demand
  - Rainfall / Irrigation

- RECORDKEEPING

MAWN Data

- Daily reference evapotranspiration is calculated by summing the hourly Penman-Monteith calculations from meteorological data at each station
- Considers temperature, solar radiation, humidity and wind speed
- International Standard for reference ET
- Estimates the crop water use for a standing grass with ample water supply

Rainfall measurement

- Measure in each field
- Should be read each day that a rain event occurs
- Record time reading is taken – should be consistent
- Keep Clean
- Install away from obstructions
- Basic gauges must not be allowed to freeze
- http://www.agweather.geo.msu.edu/mawn/
Rain Gauges

- Basic unit – 2 inch opening
- Cost less than $10.00
- 1-800-647-5368

Traditional NEXRAD

Michigan NEXRAD Tool

- Web-based tool
- Combines NWS Doppler Radar Network daily rainfall estimate with the power of Google Maps
- Site specific NEXRAD estimate of rainfall
- 2.5 mile resolution
- Base level is free to use
- Optional e-mail / text message data for a fee
- Other states are also available

www.spatialrainfallconsulting.com/Michigannexrad.html

Michigan NEXRAD Tool

www.spatialrainfallconsulting.com/nexradrain.html
Soil Water Balance

- Scheduling is very much a “checkbook” type method for accounting on a daily basis the following components
  - Rainfall / Irrigation in (Rain gage / Pumping Records)
  - Evapotranspiration out (Ref Et * Crop Coefficient)
  - Storage in the soil reservoir (H₂O capacity * Root Depth)
    - Water holding capacity
    - Increasing soil storage capacity with crop rooting depth

Tools Available

- Scheduling Tools
  - Checkbook registers
  - Scheduling software
  - Daily ET estimates
    - Simple Estimates
    - Complex Estimates
Example Problem

Questions
### Summary of Websites

- Irrigation Scheduling Checkbook Method – U. of Minnesota Extension
  - [http://www.msue.msu.edu/stjoseph](http://www.msue.msu.edu/stjoseph)
- MSU Irrigation Page
  - [www.msue.msu.edu/~northco2/irrigation/](http://www.msue.msu.edu/~northco2/irrigation/)
- Michiana Irrigation Scheduler
  - [www.agry.purdue.edu/irrigation/IrrDown.htm](http://www.agry.purdue.edu/irrigation/IrrDown.htm)
- MSU Excel Version of Scheduler
  - [http://www.agweather.geo.msu.edu/mawn/irrigation/](http://www.agweather.geo.msu.edu/mawn/irrigation/)
- Irrigation Scheduler V 4.0
  - [http://www.agweather.geo.msu.edu/mawn/](http://www.agweather.geo.msu.edu/mawn/)
- Michigan NEXRAD Tool
  - [www.spatialrainfallconsulting.com/Michigannexrad.html](http://www.spatialrainfallconsulting.com/Michigannexrad.html)
Irrigation System Evaluation
Why and How

Lyndon Kelley
MSU Extension/Purdue University Irrigation Management Agent

WWW.msu.edu - find St. Joseph Co. - then hit the Irrigation button

Have you seen yield map patterns that match the irrigation system configuration?

Irrigation System Uniformity

An 1” application should be 1” everywhere in the irrigated field

• 10% or less deviation from the average is ideal
• Over applied area will likely be over applied each application
• Under applied areas will likely be under applied each application

A 30% deviation on a field in an 8” irrigation application year will have areas receiving as little as 5.6” and as great as 10.4”

Repair all visible system leaks and problems first.

Low Uniformity

= Under Application in areas
= reduced yields

A 30% deviation in application uniformity can result in a 40% yield reduction in low application areas of the field.

Water savings
= Energy Savings
= Reduced Expenses
= Increase Profitability

• A 30% deviation on a field in an 8” irrigation application year will have areas receiving as little as 5.6” and as great as 10.4”
• To over apply by 30% to make up for lack of uniformity will take an additional 2.4” of water.
• With average energy cost nearing $3.00/acre”
• A typical 140 acre irrigated field with a 30% deviation will cost over $1000/ year more than uniform system

Stick with the Plan!!!!

Make sure the system is with in it’s design.

• Has the system changed in length or coverage area.
• Is the water supply flow and pressure what was designed for?
• Sprinkler height?
• End drive changes?
• Tire changes?
Irrigation System Uniformity

• Over 20 Irrigation uniformity trainings since May 2005

• Private consultants, Farmers, Extension, SCD, and NRCS personal

Evaluating Irrigation System Uniformity

Standards and Methods for Evaluation of Irrigation System Uniformity

• Two commonly accepted standards or methods are available as guidelines for performing evaluations of Irrigation System Uniformity.

• ASAE Standards (436.1) — Available at: http://www.kbs.msu.edu/mgsp/resources.htm


Irrigation System Uniformity

Basic System Evaluation

Collect enough uniform container to place every 10 feet the length of the system or across the application pattern.

Spread the container every ten feet from the center point to the outside edge of the application area.

Run the machine at standard setting over the container.

Measure and record the water volume caught by each container

Note sample point varying greater than 50% of the average.

Evaluating Irrigation Uniformity Catch can stands

A simple, inexpensive catch can stand can be built using:

1. 32 oz. Deposable soda cup (Taco Bell cup)
2. 3” plastic drain pipe cut to 5” in length
3. 2”x3” stud cut to length to wedge into plastic drain pipe
4. Drill hole 1.5” into cut 2”x3” stud chucks, drill hole should snugly fit electric fence post
5. Steel (step in) electric fence post

Electric fence post and cups can be stored and transported in separate stacks. The 2”x3” stud chucks wedge into the base of the cut plastic drain pipe sections and make the transition between the cup and post. Screw maybe place through the side of the plastic drain pipe into the 2”x3” stud chucks.

Total cost per unit is less than a dollar and require only a saw, drill and screw driver. It will allow data collection.

Evaluating Irrigation System Uniformity

Pivot Extensions (cornering arm or Z-arm)

• Some center pivot irrigation systems are designed to expand the wetted area to allow coverage of corner of odd-shaped fields, often referred to as cornering arms or Z-arm.

• These systems require two separate evaluations if the extension accounts for 30 percent or more of the irrigated portion of the field.

• One evaluation will evaluate the system while extended, and a second when the arm is not deployed.

Field #9
Irrigation System Uniformity

- Most systems are designed to have 90% or better uniformity
- Changes in volume and pressure from design parameters will cause reduction in uniformity
- Some sprinklers can perform well over a large change in pressure over others
- Multiple overlaps tend to reduce potential problems

Greatest improvement needed

- End gun stop adjustment
- Water supply over or under design
- End gun orifice, too little or too much
- Wrong sprinkler or tip
- Leaks, plugs and no turn sprinklers
Water supply over or under design

Example of Water supply under volume for sprinkler design

Over and under application issue affect the majority of the application area
Improving Traveler Uniformity

- Check traveler uniformity by placing catch cans every 10' across the width of the coverage pattern.
- Traveler lane spacing should be adjusted to create an even application between lanes.
- Spacing will be narrower further from pump or additional pressure will need to be provided.

Improving Traveler Uniformity

- Measure traveler forward speed at the beginning, middle, and end of the run.
- Traveler forward travel speed may be reduced as more hose is being pulled in the second half of the run.
- Adjust speed accordingly.

Solid set and manual move system uniformity

- Stick with the Plan!!!!

Make sure the system is within its design.
- Has the system changed in length or coverage area.
- Is the water supply flow and pressure what was designed for.
- Sprinkler height?
- ......
Most systems apply within 85% of the expected application. Application is 4% under expectation.

Measure flow at desired pressure prior to ordering sprinkler package. Poor performance: Ask dealer to measure flow at peak water use season and compare to design parameters.

Preventing Irrigation Runoff (comparing irrigation application rate to soil infiltration rate)

Sprinkler package or nozzle selection along with pressure dictates water application rate. Factors that increase runoff:
- Small wetted area or throw of sprinkler
- Low pressure
- Larger applications volumes
- Soil compaction
- Heavy soils
- Slope
- Row hilling
Instantaneous Application Rate

John applied .75 inches in 21 minute

\[ .75 \text{ inches} = 1.00 \text{ inches} \]
\[ 21 \text{ min.} ? = 28 \text{ min.}/\text{inch} \]

Preventing Irrigation Runoff

(comparing irrigation application rate to soil infiltration rate)

Management factors that increase runoff:
- Larger applications volumes
- Soil compaction
- Heavy soils
- Slope
- Row hilling
- Dropped or low elevation sprinkler
- Small wetted diameter

The larger the wetted area the slower the rate of application. Average 1' rainfall comes over 4 hours.

An 1' rainfall over an hour is considered a "toad strangler"

Sprinkler packages are commonly available with instantaneous application rates from 1" per 12 minutes to 1" per 80 minutes
Irrigation Energy Options and Considerations

Lyndon Kelley
MSU Extension/Purdue University
Irrigation Management Agent
269-467-5511

- then hit the Irrigation button

Irrigation power cost vary on:
- power source
- power cost
- system pressure

Average fuel cost for pumping NE. USA: 2006
Cost per acre inch of irrigation water

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Electric</th>
<th>Diesel / propane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low &lt;35 psi</td>
<td>$1.76</td>
<td>$2.56 / 2.30</td>
</tr>
<tr>
<td>Med. 35 to 95 psi</td>
<td>$2.48</td>
<td>$3.76 / 3.27</td>
</tr>
<tr>
<td>High &gt;100psi</td>
<td>$3.56</td>
<td>$4.87 / 3.90</td>
</tr>
</tbody>
</table>

Power Options

- All Electric System
  - electric to power the pump
  - electric to drive irrigation unit

Do you have access to a 3-phase, 480V power line?

Combination Systems

- Engine Power & Electric
  - engine to power the pump & electric drive irrigation unit
  - electric power to be supplied by local utility
  - phase converter needed on a single phase lines

All Engine Power System

Engine power to pump water
Commonly used with high psi
- Solid set irrigation units
- Soft hose & hand hose irrigation units (water drive)

Engine powers 3 phase, belt driven generator or hydraulic pump to drive pivots.
Determining the Power Source
Most Economical for Your Farm

It depends on the power options available at your site

When readily available electricity is almost always the choice.

What are your Electrical Options

• Is electric available for your site or can it be brought in economically?
• Do you have 3 phase or single phase service?
• Can single phase system and a phase converter be used to power pivot at your site?
• Area cost of electricity (3.5 to 13.4 cents/Kw/hr)
• Reliability of electrical service areas vs. your skill at generating power.

Variable Frequency Drives

• Common for 20 hp and less
• Can be single phase powered
• Allows an effective use of portion of the total output
• About double cost/hp

What are your Engine Power Options

• Tractor PTO driven equipment
• Engine power equipment
  Diesel, gasoline, or propane

What Type of Power Sources are Required for Your Irrigation System

• Most pivots require electric to move the system. Exception: hydraulic drives.
• Most traveler systems use water pressure-piston, impeller or water wheel.
• Safety system may run from engine.
• Solid set and hand move systems use just the water pressure.

A determination of power options available in your location needs to be made during the planning stage of your irrigation system.

1. Water availability
2. Power availability
3. Potential acres to irrigate
4. Actual acres coverage
5. Minimum pressure needs
Power Systems & Your Irrigation Equipment Investment

- You need to calculate equipment investment costs depending on power choices available.
- You need to calculate daily power operation costs (electronic vs. fuel costs). They can be site specific.

Installation Cost

Assuming no electric service currently at site
- Determine the cost to bring in 3-phase service vs. an engine power system

Assuming electric service available, but only single phase
- Determine the cost to install phase conversion equipment to run irrigation unit and engine power to run pump vs. all engine power

No electric service
- Determine the cost to install on-farm electric generator vs. engine power system

3-Phase electric service
- Determine the cost of equipment for all electric power irrigation equipment vs. all engine power equipment

Irrigation Energy Options- Decision consideration

Always do your own homework, every situation is different

Quick and dirty cost comparisons

high cost to low cost

Annual energy cost
- gasoline > diesel > propane > electricity

Initial equipment and infrastructure cost
- diesel > propane > gasoline > electricity

Annual maintenance, repairs, labor
- diesel > gasoline > propane > electricity
Day to Day Power Operation Costs

<table>
<thead>
<tr>
<th>Source</th>
<th>Diesel ($/gallon)</th>
<th>Propane ($/gallon)</th>
<th>Gasoline ($/gallon)</th>
<th>Electricity (kw-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE-111</td>
<td>1.75</td>
<td>1.31</td>
<td>2.00</td>
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</tr>
<tr>
<td></td>
<td>1.94</td>
<td>1.49</td>
<td>3.00</td>
<td>2.37</td>
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<td>2.13</td>
<td>1.66</td>
<td>3.93</td>
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<td></td>
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<td>2.77</td>
<td>2.39</td>
<td>3.53</td>
<td>2.30</td>
</tr>
</tbody>
</table>

Table 2. Comparative Costs of Various Energy Sources to Obtain Equal Work Output per Dollar Spent

Source: All-335 Comparable Costs of Various Energy Sources (1989-89)

Investigate Propane:
- About 1/3 saving in pumping cost ($2.50 diesel = $1.50 propane)
- Less fuel theft problems
- Minimal environmental storage, exhaust concerns
- Off season use grain drying tank
- No water in fuel issues
- Lower initial investment

If considering electric—what are the Electric Load Management Options your utility offers Electric Irrigation System Operators

Commercial Energy Rate
- Off peak electric rate cost/kWh
- On peak electric rate cost/kWh
- Time of day operation restrictions
- Shut down concessions
- All considered actual rate can be from 2.3 cent to 13.4 cents / Kilowatt hour.

How automated do you need your system to be? (Computer controlled systems)
- All electric systems easiest to control automatically.
- More difficult to automate and computerize engine power irrigation systems.

http://ipat.sc.egov.usda.gov/